XIII. *Observations of the diurnal Variation of the Magnetic Needle at Fort* Marlborough, *in the Island of* Sumatra. *By* John Macdonald, *Esq. In a Letter to* John Crisp, *Esq. F. R. S.*

Read April 21, 1796.

DEAR SIR, Fort Marlborough, 15th March, 1795.

I HAVE now the satisfaction to transmit to you the observations of the diurnal variation of the variation of the magnetic needle, with which you wished to be furnished. A short account of the mode used in laying off the meridian is prefixed. A small building, devoid of iron, was erected at some distance from my house. This building contained the meridian. By repeated observations, I found the sphere of mutual attraction of the needle and iron to be very small; a common-sized key presented to it, did not affect it at a nearer distance than 5 inches. To exclude every influence of iron, I laid aside such as might be about me, previous to the taking of the observations, and took care to remove the padlock and key, at the same time, to a certain distance from the constructure. The hasp and staple made use of for the padlock were of wood; and for the nocturnal observations, I had wooden candlesticks made. I may venture to say, that the observations were taken with the utmost care; and that every requisite precaution was used to exclude errors that might have arisen from a want of minute attention.

The observations contained in pages 346, 347, and 348, were taken by applying the magnet-box three times, each day, to the meridian. This was, I think, accurately effected, by hairs fixed longitudinally on the inside of the box, corresponding with projecting points on the outside. When these covered each other, and the meridian, to the eye looking through a magnifying glass from above, there was a strong presumption that the longitudinal axis and 0° points of the box were on and in the true plane of the meridian. In reading off, the right hand covered the right eye; a magnifying glass, of a power of $2\frac{1}{2}$, was held in the left hand; the upper axis-hair was brought to cover the 0° point; and the eye, hanging over this point, glanced steadily to the left, to read off the variation west from south, as the fine minute-scale was placed on the flat south end of the needle. This observation was taken each time four times, to ensure accuracy. Lest, however, any error might have arisen from not placing the box accurately in the same situation, in taking the three daily observations, two pieces of seasoned wood were fixed with wooden pins, nearly parallel to the meridian, on either side. The magnet-box was applied to the meridian between these, and kept firmly fixed in its position by a number of small wooden wedges, urged gently between the box and the lateral fixtures. The observations contained in page 349 were taken with the magnet thus fixed. A fourth column of observations, at various nocturnal hours, is given in page 349. A corresponding thermometrical observation is attached to each magnetic one. The thermometer was placed in the room on the left side of my hall.

It appears from these observations, that the east variation

diurnal of the variation, increased from about 7 in the morning till 5 in the afternoon, and that it decreased till 7 in the morning. The irregularities which are apparent do not destroy the general evident inference of result, as it is well known that the common increasing or decreasing variation is subject, in the same place, and on the same day, to certain deviations, from latent causes. It appears in general, that such diurnal variation of the variation as had been observed during thunder, is greater than it ought to have been, *cæteris paribus*.

It has been remarked, that heat weakens the magnetic virtue, and that cold strengthens it. Supposing, with the great HALLEY, the existence of 4 magnetic poles, by blending this supposition with the above principle, well ascertained, attempts have been made to account for the diurnal variation of the variation. The south-east magnetic pole being less heated in the morning, either by the sun or by subterraneous fire, than towards noon, and in the afternoon, and being at the same time, by passing through the meridian of Celebes, nearer Sumatra than the south-west magnetic pole, it draws to it in the morning the south end of the magnetic needle more powerfully than the other attracts; and, consequently, the variation diurnal of the variation ought to be, and actually is, less in the morning than in the afternoon. In the progress of the day, the south-east magnetic pole having become heated, and the south-west pole being at the same time less heated, attracts the south end of the magnetic needle more powerfully than the other does; and hence the east diurnal variation of the variation appears greater in the afternoon than in the morning. It is found in Europe, that this diurnal variation of the variation is greater in summer than in winter. This seems to point out

heat acting on magnets in the earth, as its efficient cause. This was first observed in Europe in 1756, by Mr. CANTON; and the results of the foregoing observation being diametrically opposite to his, with similar effects, afford not a small confirmation of the essential part of HALLEY's theory. The sciences of electricity and magnetism (in my opinion intimately connected) are at present in their infancy. We observe effects which we cannot trace up to any satisfactory cause. If observations similar to these, and to those made by Mr. CANTON, could be made in equal latitudes and longitudes, and in corresponding situations in the torrid zone, by collating the results, I think a rationale of this wonderful phænomenon might be obtained.

From the greatness of the angle of dip of the needle, I am led to suppose that the magnetic poles are fixed within the magnetic nucleus far within the earth's surface, and that some of these poles are more powerful in their action than others, from the variation observed in various places of the globe. I shall be happy if these observations (I mean the figured ones) will enable you to elucidate this subject.

I remain, with much esteem, &c.

JOHN MACDONALD.

24th of June. A meridian was drawn by means of the following apparatus. A plate of brass was cast, and reduced to a level surface in a lathe, in which concentric circles were accurately cut on it. A short hollow cylinder was screwed on the centre. This tube received a brass cylinder, pointed at the upper end. An iron-wood post was fixed in the ground. The brass plate was fixed level on the post by means of a gunner's

perpendicular, and strong screws working in two plates, on the principle of the levelling screws of a theodolite. The cylinder was rendered perfectly perpendicular to the level plate, by means of three small adjusting screws on the tube. These screws acting laterally on the brass wire-pointed pin that gave the sun's shadow on the concentric circles, brought it perpendicular over the centre of the plate. A flat small brass ruler was furnished with a socket, which received the point of the shadow-pin. This ruler had a horizontal arm to it, having a semicircle at one extremity coinciding with the tube on the centre of the plate. A pointed wire passed to the plate through the other extremity of the horizontal arm. This wire could be raised or lowered at pleasure by a small screw. It is evident that if this point touched, *delicately*, the plate of brass, in moving it round (by means of the socket above, and semicircle playing round the tube below), the shadow-pin must be perpendicular. If the plate was acted upon evidently *roughly* by the pin in moving horizontally, it is clear the pin must be inclined to that side, and a delicate correction was given by the little brass screws fixed to the tube screwed on the centre. By this contrivance the shadow-pin was fixed exactly perpendicular to the plate.

The box in which the magnet is suspended seems to have come out of the maker's hand unfinished, having on it no hairs through, or parallel to its axis, by which to apply it truly to a meridian. These hairs were fixed above and below the magnet, in a plane perpendicular to the graduated o° at both ends. Two very fine brass wires were fixed on the outside, on the ends of the box. These brass wires were in the plane of the hairs, and when applied to the meridian, the hairs

appeared to cover the meridian, through circular holes in the bottom of the box. I may venture to assert that the meridian was laid off within one minute of a degree, as it bisected the chords of 12 different arcs of concentric circles made use of. I may also say that the axis, or 0° line of the box, was applied to the meridian within one minute of true position. In laying off the meridian, the operations of two successive days perfectly agreed.—W. or E. put over each observation, indicates west or east variation. As bad weather may prevent observing at the specified hours at the heads of the columns, the hour, if different from 7 A. M. 12 or 5 P. M. or from others at the heads of columns, will be marked over those particular observations.

N. B. In the weather columns, to save trouble, F. means fair, A. after, R. rainy, N. night, L. lightning, C. cloudy, S. sky, T. thunder, m. much, O. overcast, s. serene, W. windy, l. little.

1794.	Time. 7 A.M.	Thermometer.	Time. 12.	Thermometer.	Time. 5 P.M.	Thermometer.	1st Observation. Weather.	2d Observation. Weather.	3d Observation. Weather.
	E.		E.		E.				
June 27	1 8 6	74	1 10	81	1 12	81	F. A. a R. N. C.	a north-west wind	R. O. and W.
28	1 8	78	1 10	78	1 12	80	m. R. in the N. and some L.	C. sun at intervals	a l. C.
29	1 8	76	1 10 2½	83⅓	1 11	82	C. - -	s. sunshine	C. and sultry
July 1	1 7	76	1 11 2	84	1 11	82	s. sunshine	west wind, sunshine	s. wind north-west
2	1 9	76	1 10	82	1 12	82⅓	a clear morning	s. sunshine	s.
3	1 9	78	1 11	82¼	1 9	82	a clear morning	s. ditto, wind west	s.
4	1 9	74⅓	1 7	82	1 8	82	a l. C.	s. sunshine	a l. C.
5	1 6	76	1 7	81⅔	1 10	82	s. - -	s. ditto - -	s. and sunshine
6	1 9	76	1 11	82	1 12	81½	C. - -	s. sunshine	C. R. and distant T.
7	1 9	76	-	-	1 10	81	C. - -	- -	s. sunshine
8	1 9	77	1 10	82	1 10	82	a l. C. - -	s. sunshine	s. ditto
9	1 6	78	1 9	82	1 10	82	a s. S. - -	s. ditto -	s. ditto
10	1 6	75	1 10	81⅔	1 10½	83	a s. S. - -	s. ditto - -	s. ditto
11	1 9	76	1 9	82	1 10	84	C. and O.	s. ditto - -	s. ditto
full moon. 12	1 9	76	1 10	82½	1 8	83¼	a s. S. - -	s. ditto -	s. ditto
13	1 9	75	1 10	83⅔	-	-	a s. S. - -	s. ditto	
14	1 9	78⅓	1 10	83⅔	1 8	84⅓	a clear morning	s. ditto -	s. ditto
15	1 9	79	1 9	84	1 9	84	a ditto - -	ditto - -	s. ditto
16	1 9	74⅓	1 8	83	-	-	a calm clear morning	s. ditto	
18	1 8	76	1 9	82	1 10	81	C. - -	s. ditto -	distant thunder, C.
19	1 9	73⅔	1 10	83	1 9	82	s. sunshine -	a l. C. - -	R. A. T.
21	1 8	79	1 9	83	-	-	s. south-east wind	C.	
22	1 9	74	1 11	77	1 10	79	C. and R. -	C. and R. -	C.
23	1 9	76	1 9	83	1 9	80	C. - -	s. sunshine	C. and R.
24	1 9	74	1 9	82	-	-	s. sunshine -	s. ditto -	
25	1 9 8	75⅔	1 10	83	-	-	s. ditto - -	s. ditto -	
new moon. 26	1 9	77	1 7	84	1 9	84½	s. ditto -	s. ditto -	s. sunshine
27	1 8	74⅔	1 10	84	1 9	83½	s. ditto - -	s. ditto - -	s. ditto
28	1 8	75⅔	1 10	83	1 8	82⅓	C. - -	s. ditto -	s. ditto
30	1 9	72½	-	-	-	-	s. sunshine		
31	-	-	1 9	82	1 8	82	- - -	s. ditto - -	s. ditto

1794.	Time. 8 A.M.	Time. 12.	Time. 4 P.M.	Thermometer.	Ditto, 2d observation.	Ditto, 3d observation.	1st Observation. Weather.	2d Observation. Weather.	3d Observation. Weather.
	° ′	° ′	° ′						
	E.	E.	E.	°	°	°			
Aug. 1	1 7	1 8	1 9	77 2/3	84	82	s. sunshine	s. sunshine	C. Thunder
2	1 8	-	-	77 1/2	-	-	s. ditto		
3	1 6	1 8	1 9	79	82 1/2	82	s. ditto - -	s. ditto -	C.
4	1 7	1 8	-	-	82	-	s. ditto -	s. ditto -	
6	1 7	1 8	1 7	78	83 1/2	83	s. ditto -	s. ditto -	C. Thunder
7	1 8	1 8	1 8	80	82	81	s. ditto - -	s. ditto - -	R. C. and distant T.
8	1 8	1 8	1 8	75	77	78 1/2	C. A. m. R. in the N.	C. and O. -	C.
9	1 8	1 6	1 8	76	82	82	s. sunshine	s. sunshine -	s. sunshine
10	1 6	1 6	-	76	82	-	C. - -	s. ditto -	s. ditto
12	1 6	1 6	1 9	78	82	82	s. sunshine	C. - -	C. and T.
13	1 8	1 6	1 9	78	82	82	s. ditto -	distant Thunder	C. R. and T.
15	1 7	1 7	1 10	79	81	81	s. ditto - -	s. sunshine -	R. and C.
16	1 8	1 8	1 7	77	81	79	C. - -	s. ditto -	m. R.
18	1 8	1 9	1 8	78	81 1/2	80	C. -	C. - -	C. and high wind
20	1 9	1 6	1 8	77 1/2	80	82	C. - -	C. a l. - -	s. sunshine
21	1 8	1 7	1 9	78	83	83	s. sunshine -	s. sunshine -	s. ditto
22	1 7	1 8	1 10	76	78	78 1/2	C. and R. -	C. R. -	C.
23	1 8	1 6	1 9	76	80	78 1/2	C. -	C. a l. - -	s. sunshine
25	1 7	1 7	-	77	81 1/2	-	s. sunshine -	s. sunshine -	C. distant T.
30	1 7	1 8	1 9	76	82	81	a l. C. - -	s. ditto -	C. distant T.
31	1 8	1 6	1 8	77	82	79 1/2	F. A. R. -	C. - -	s. A. R.

N. B. It was, from forgetfulness, omitted to take and insert the thermometrical observation which should have been attached to the morning variation of the 4th. It is, however, a matter of little consequence in the general consideration of the subject.

1794.	Time. 9 A.M.	Thermometer.	Time. 12.	Thermometer.	Time. 3 P.M.	Thermometer.	1st Observation. Weather.	2d Observation. Weather.	3d Observation. Weather.
	o /	o	o /	o	o /	o			
	E.		E.		E.				
October 1	1 8	80	-	-	1 9	80¼	s. sunshine	R. A. C. S.	
2	1 6	77	1 8	82	1 8	83	s. A. R. -	A. l. C. -	s. sunshine
4	1 6	78	1 9	82	-	-	s. sunshine	s. sunshine	
5	1 6	80	-	-	1 8	84	a l. C. -	- -	ditto
8	1 6	78	1 10	83½	1 10	84	s. sunshine	s. sunshine	s. ditto
9	1 6	79	-	-	-	-	ditto		
10	1 6	78	1 9	81	1 10	83½	C. - -	s. ditto -	distant T. sunshine
	10								
12	1 6	79	1 8	82½	1 9	82½	s. sunshine	s. ditto -	C. distant T.
14	1 8	79	-	-	-	-	s. ditto		
15	-	-	1 8	82½	-	-	- -	s. ditto	
16	1 7	80	1 7	83	1 7	84	a l. W. -	s. ditto -	sunshine and W.
17	1 6	79½	1 7	83	1 9	84	s. sunshine	a l. C. -	ditto s.
18	1 5	78	1 8	81½	1 8	80¼	C. - -	s. sunshine	C.
20	-	-	1 10	83	-	-	- -	s. ditto	
	10								
21	1 8	80	1 9	84¼	1 10	85	s. sunshine	s. ditto -	distant T. s.
22	1 6	78	1 8	84	-	-	s. ditto -	s. ditto a l. W.	
23	1 5	77½	1 9	83	1 9	83	F. A. R. -	s. ditto a l. W.	s. sunshine a l. W.
					4				
24	1 5	79	-	-	1 8	82	F. C. - -	- -	a l. C. F.
25	1 4	78	1 9	81	1 9	80¼	a l. C. A. R.	W. and C.	W. and C.
27	1 5	77½	1 7	79	1 7	78	C. and W. A. m. R.	C. and W.	C. W. very rainy
28	1 4	78	1 8	80	1 9	80½	a l. C. A. m. R.	C. - -	F. s. sunshine
29	1 5	78½	1 9	81	1 9	81	C. and W.	C. and W.	C. and W.
30	1 8	79½	1 9	79⅓	1 10	79⅔	a l. C. -	ditto -	a l. C. s.
31	1 4	78½	1 8	82	1 8	82½	a l. C. -	s. sunshine	s. sunshine
Novem. 1	1 5	78	1 11	82½	1 9	82½	s. but C. -	a l. W. sunshine	a l. W. sunshine
3	1 8	78	1 10	83	1 10	84	s. sunshine	s. ditto	s. sunshine
4	1 7	79	-	-	1 11	83⅔	s. ditto -	- -	s. sunshine
8	1 4	79	1 9	82	1 9	79	s. a l. C. -	sunshine a l. W.	s. but C.
10	1 6	78½	-	-	1 9	84	s. sunshine	- -	s. sunshine
11	1 6	78	1 12	82	1 8	83¼	F. A. m. R. and T.	s. a l. C. -	C. and distant T.
12	1 6	77	1 9	84	-	-	sunshine a l. W.	a l. C. distant T.	
14	1 5	78	1 10	85	1 11	81	s. sunshine	sunshine W. and T.	R. C. and distant T.
15	1 4	76¼	1 9	82¼	1 10	83	s. but C. -	sunshine a l. W.	s. sunshine
17	1 5	79	1 10	83¼	1 9	81	a l. C. -	s. sunshine	C. A. R. with T.
19	1 7	78½	1 7	82	1 9	81½	s. sunshine	At 5 min. before 11 a very violent earthquake—d°	s. but C.
21	1 7	77½	-	-	1 11	82½	s. sunshine	s. sunshine	s. sunshine
22	1 5	76	1 8	81½	1 8	82	a l. C. A. m. R.	a l. W. -	s. ditto
Decem. 5	1 4	77½	1 9	82½	1 9	82	s. and F. A. m. R.	a l. W. -	sunshine a. l. W.
10	1 6	77	1 7	80	1 8	81	F. A. m. R.	C. and rainy	a l. C. and W.

1795.	Time. 7 A.M.	Thermometer.	Time. 12.	Thermometer.	Time. 5 P.M.	Thermometer.	Various Hours.		Thermometer.	1st Observation. Weather.	2d Observation. Weather.	3d Observation. Weather.	4th Observation. Weather.
	° ′	°	° ′	°	° ′	°		° ′	°				
	E.		E.		E.			E.					
Jan. 17	1 6	77⅔	1 8	82	1 7	78	- -	-	-	C. A. R.	C. strong west wind	C. A. and T.	
19	1 6	78	1 10	84	-	-	-	-	-	s. sunshine	s. distant T.		
20	-	-	1 10	83½	-	-	-	-	-	- -	s. sunshine		
21	1 6	77½	1 12	82½	1 9	81½	2 P. M.	1 10	82½	a l. C. s. -	s. sunshine	s. a l. C. -	distant T.
22	-	-	1 10	78¼	-	-	10 A. M.	1 8	76	- -	C. - -	- -	C. A. m. R. in the N.
23	-	-	1 10	79	1 9	79	2 P. M.	1 10	76⅔	- -	s. a l. C. -	s. a l. sunshine	C. a high north-west wind
24	1 6	75¼	1 10	81⅔	1 10	82	-	-	-	s. sunshine	s. sunshine -	s. sunshine -	
26	1 7	77	1 9	81	-	-	2 P. M.	1 10	82	a l. C. s. -	s. sunshine	- -	s. sunshine
28	1 5	74	1 8	77	1 7	75	9 A. M.	1 6	75	C. A. m. R.	C. with R. -	C. a l. R. -	C. A. m. R.
29	1 8	73	1 9	81	-	-	12 P. M.	1 8	77	s. sunshine -	a l. C. -	- -	a fine N.
30	1 7	74	1 9	81	1 9	82	11 P. M.	1 8	78	s. sunshine	s. a l. C. -	S. a l. C. -	a fine s. N.
31	- -	-	1 8	82	-	-	-	-	-	- -	s. sunshine		
Febr.	8 A.M.				4 P.M.								
2	-	-	1 10	84	-	-	-	-	-	sunshine, a l. W.			
3	-	-	-	-	-	-	10 P. M.	1 7	78¾	- -	- -	- -	a fine N.
4	1 6	75⅔	1 8	79⅔	-	-	11 P. M.	1 7	76½	s. a l. C. -	s. a l. C. -	- -	a s. fine N.
5	1 5	76	1 10	84	-	-	10 P. M.	1 9	82	s. a l. C.	sunshine, a l. W.	- -	a s. fine N.
6	1 6	78	1 9	84	2 1 10	84½	12 P. M.	1 7	80	F. a l. W. -	a l. W. -	s. sunshine -	a s. fine N.
7	1 6	78	-	-	-	-	11 P. M.	1 7	79	a strong wind	- -	- -	a fine N.
8	1 7	79	1 11	82½	-	-	-	-	-	s. and mild -	very W.		
9	1 7	79	1 11	82	1 11	82¼	11 P. M.	1 8	78	s. sunshine	a l. W. -	a l. R. and C.	a C. N.
10	1 8	77½	1 7	82	1 9	84½	-	-	-	s. sunshine -	s. sunshine -	s. a l. C.	
11	1 7	77	1 10	84	-	-	11½ P. M.	1 9	79⅔	s. sunshine -	distant T. -	- -	a s. fine N.
12	1 6	76	1 8	82	1 11	84½	10 P. M.	1 7	79	s. - -	s. sunshine	s. sunshine, and distant T.	a C. N.
13	1 7	78	1 8	84½	1 8	79	-	-	-	s. sunshine -	distant T. -	R. and T.	
14	- 6	-	1 10	82½	1 10	81¼	10 P. M.	1 9	78	- -	loud T. C.	s. and C. -	a s. C. N.
16	1 8	76	1 8	83	1 8	84½	7 P. M.	1 10	80	s. A. m. T.	a C. S. -	distant T. -	heavy near T. & L.
17	1 7	78	1 8	83	1 10	84½	11 P. M.	1 9	80	s. sunshine -	s. sunshine	s. sunshine -	a s. C. N.
22	-	-	-	-	-	-	2 P. M.	1 11	84½	- -	- -	- -	s. sunshine
23	1 9	78	-	-	-	-	1 P. M.	1 10	84⅔	s. sunshine	- -	- -	s. ditto
26	-	-	-	-	-	-	3 P. M.	1 9	76	- -	- -	- -	a C. N.
27	1 10	77	-	-	1 11	84	-	-	-	s. sunshine -	- -	s. sunshine	
28	1 9	79	1 11	84	1 11	83½	-	-	-	s. ditto -	a l. W. -	distant T.	
Mar. 11	1 6	79	1 8	83	1 10	80	11 P. M.	1 8	77	a high wind	a high wind	a high wind -	a C. N. A. R.
12	1 6	78	1 8	80	-	-	11¼ P. M.	1 8	76½	C. and W. -	C. R. and W.	- -	a l. R. and C.
13	1 6	77	1 10	82	1 9	81	12 P. M.	1 8	78¼	a l. C. A. R. N.	s. sunshine -	s. a l. C. -	a s. N.
14	1 6	79	1 10	83	1 10	82	12 P. M.	1 8	79	s. sunshine	s. a l. C. -	s. and C. -	a R. N.
16	1 6	78	1 9	84	1 10	82	12½ P. M.	1 9	79	s. ditto -	s. sunshine		
17	1 6	79	1 8	82	-	-	-	-	-	- -	- -	- -	